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Construction Systems for Detached, Single-story Concrete Block Houses in Florida: Current Practices, Costs and Potential Innovations

Randolph DeShields McDonald
University of Central Florida

CONSTRUCTION SYSTEMS FOR DETACHED, SINGLE-STORY CONCRETE BLOCK HOMES IN FLORIDA: CURRENT PRACTICES, COSTS, AND POTENTIAL INNOVATIONS

By

RANDOLPH DESHIELDS MCDONALD
B.E.E., University of Florida, 1954

RESEARCH REPORT

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ABSTRACT

CONSTRUCTION SYSTEMS FOR DETACHED, SINGLE-STORY CONCRETE BLOCK HOMES IN FLORIDA: CURRENT PRACTICES, COSTS, AND POTENTIAL INNOVATIONS

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Concrete block single-story detached homes are popular residences in Florida, but construction materials and methods must undergo changes to combat rising prices and material shortages. Those systems with the greatest pressure of price or material shortage will change first.

When current costs and methods are examined, it is found that two systems, roof and exterior walls, have the greatest need for changes in the immediate future; and one system, thermal insulation, needs an empirical study. The roof is of materials which are in short supply and rapidly increasing in cost. The study concludes that, with present cost trends, metal frame members for the roof or a reinforced concrete slab roof are feasible alternatives. The exterior walls have excessive labor costs, and the feasible alternative may be cast-on-site masonry tilt-up panel walls.

Power prices, electrical and fuel, create a need to establish new guidelines for the extent of home thermal insulation. The heat gains and losses are examined to direct future studies of the home's thermal insulation problems.

The concrete block home will continue to be viable if the necessary innovations are implemented to reduce cost rate of increase and to reduce operating and maintenance costs.

Approved by:

George F. Schrader

George F. Schrader
Director of Research Report

INTRODUCTION

Housing construction rate has risen to over two million units per year, creating a heavy drain on the national resources of labor, manufacturing capacity, and material. The continuing inflation and shortages affecting home construction suggest that a study of the current practices and materials used in home construction is timely.

Since concrete block single-story homes are popular and practical in Florida, they have been selected for this paper. Systems constituting the shell (floor, exterior wall, roof) have unique features of cost, quality, and assembly method.

The purpose of this paper is to examine the shell systems to the depth necessary to determine a need for alternatives, compare available alternatives, and propose viable innovative systems, which may reduce costs and/or improve quality.

Systems for concrete block home construction of most interest are those which may be accomplished today, using available materials and skilled tradesmen. Alternative systems, including those requiring material or techniques not yet developed or readily available, are suggested where the need is sufficiently great.

Costs are presented sufficiently to cover comparisons to common alternatives for the system or element examined.

Items, such as floor covering, which are not unique to concrete block houses are omitted. Stucco walls and tile roofs will also be omitted, although they raise the quality of the essential elements of sound transmission and thermal conduction.

The quality of each system is given as workmanship precautions, inherent characteristics, and common or costly failures which determine the satisfaction of the home owner and success of the builder.

The construction sequence was determined by observing concrete block homes under construction. These observations were guided by FHA Minimum Property Standards, the Southern Standard Building Code, a text on concrete block construction, and numerous pamphlets by the U.S. Department of Agriculture. Work crew size and techniques were determined to the extent possible with brief observation and augmentation by conversation with a local union official.

A number of firsthand observations prompted some of the quality material, including restoration of a failed foundation, roof roll off, and shingle failure. Texts on building failures and fire investigation, together with handbooks on architectural design provided reference material for quality evaluation.

Interviews with a banking home loan official and a truss company engineer helped refine and make current the material.

The reader will find information useful to anyone who intends to build or purchase a concrete block home. Those seeking new housing will find themselves beset by rapidly inflating costs, material shortages, and restrictions. Prices in Florida have been increasing at the rate of 15% a year for the last four years. For example, the average used home in 1967 was valued at $23,000. The price today is $35,000. This is not a Florida phenomena, as a 20% increase in evaluation was reported for Delaware.[1] The builder and buyer are restricted by building material specifications, sewer and water moratoriums, and zoning. Fortunately, mortgage money will be readily available; it is expected to be abundant in 1973 as a result of families going on a savings spree for the past two years.[2]

New housing must be long-lived and have low maintenance to offset the present costs. The 1968 Revision 6 to FHA Minimum Property Standards has this foreword:

> These Minimum Property Standards are to provide guidelines to aid in the development of well-planned, safe, and soundly constructed homes. It is desired that the material contained herein will stimulate innovation in techniques and material, which will result in improved and economical housing for American families.

It is in this spirit that current practice in detached single-family concrete block construction will be examined.

Those seeking subjects for further research will find, among others, a heat transfer problem, a potential plastics application, and a unique computer usage.

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[1] "Outlook for Home Buyers as the Experts See It," U.S. News and World Report, November 6, 1972, p.83.

[2] Ibid., p. 81.

CHAPTER 1

EXTERIOR WALLS AND FOOTER

A. Components

Concrete blocks are the primary element in the exterior wall system. They may be purchased in a number of forms for 8-inch wall thickness and almost as many forms for 12-inch wall thickness. For most work, up to the tenth course above floor level, 8x8x8-inch half-blocks, 8x8x16-inch stretcher blocks, 8x8x16-inch corner blocks, and 8x8x16-inch header blocks will suffice. For lintel courses, eleven and twelve, lintel blocks and pre-cast lintel are used. Where off-sizes in length are required, the blocks may be cut with a masonry blade in a common hand-held saw.

B. Assembly

The building is laid out with batter boards and twine, used to outline the foundation, and footing work is begun. Carelessness in establishing an exact location might easily result in a costly building violation.

The footer may use forms or be earth formed, as long as the required minimum dimensions are maintained.

Reinforcing steel is laid on chairs, or may be suspended from the form work with wire.

Pilaster locations must have steel extending upward from the foundation to provide vertical ties.[1]

Block laying can begin shortly after the footer is poured. The concrete will set sufficiently in one warm day. The walls can then proceed continuously to the roof level or may be interrupted at the floor level.

When interrupted at the floor level, the walls to that level may be considered as part of the foundation. The floor slab work would proceed from that point, and the work on the exterior walls would follow.

C. Cost

Material cost for an 8-inch concrete block exterior wall is calculated, using current Brevard County retail prices. The cost is determined on a linear foot basis in order that footer and lintel costs can be included (see Appendix A). The total material cost, floor to ceiling, is $4.27 per linear foot.

Footer costs are based on two courses of block from footer to floor level. Material cost is $1.45 per linear foot, giving a wall cost of $5.72.

To complete computation of material costs for a wall, three additional factors are required--one for window opening, one for the doorway, and one for the pilasters. The computations are in Appendix A.

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[1]Southern Building Code Congress, Southern Standard Building Code (Birmingham, Alabama: Southern Building Code Congress, 1969), Appendix D, "Hurricane Requirements."

Labor costs are the most difficult to estimate. To permit a comparison of systems using the same data base, Building Construction Cost Data 1970 will be used. The purpose of this paper is to present and compare systems of construction. Current costs will be used where possible, using local practices and rates.

The computed labor costs of the exterior walls (see Appendix A) is found to be $9.46 per linear foot.[1]

C.1. Prepared Item Cost Analysis

Lintels free-span the door and window opening and for most spans, may be manhandled into place by the masonry crew. The final row of lintel blocks is laid across the lintels and the lintel is poured without any batten or bracing required. Should a cast-in-place lintel be substituted, both the upper eight inches and the lower eight inches must be cast. In addition, pouring the entire lintel must be done at the same time to conform with regulatory requirements and a cost restraint. The cost restraint is due to small loads of ready-mix concrete costing a premium price. A lesser alternative to the fully-formed lintel can be accomplished by providing a spanning support for the first row of lintel blocks. This fails in two respects. The door headers require a special

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[1]Robert Sturgis Godfrey, Building Construction Cost Data 1970 (Duxbury, Mass.: Robert Snow Means Company, Inc., 1970), p. 36 and p. 47.

shape to allow for the height of the 6-foot 8-inch door, added to the 3/4-inch threshold, and the wooden header portion of the door framing. Therefore, the standard lintel blocks would require a 72-inch cut, which is an excessive cost.

The second failure is quality. The core holes of the lintel blocks will have "bug holes" in the poured cement, unless special mixes and great care is used. The choice is either pre-cast lintels or a fully formed lintel.

C.2. Costs Comparison

A material cost comparison for the lintel shows \$.98 per linear foot for pre-cast and \$.72 for a formed lintel. The extra material costs for pre-cast is about \$50 for a building 30 x 70 feet. Forming labor and material far exceed the \$50 difference.

Another saving in use of pre-cast lintel elements is that after curing for one warm day, sufficient strength exists to proceed with roofing.

When using formed-in-place lintels, several days must elapse before form removal and proceeding with roof work.

In conclusion, a uniform appearance will result from use of pre-cast lintels. There is little or no cost difference for material and labor, and work flow is less subject to interruption.

D. Quality

Masonry walls give greater durability than other commonly used material. They are fireproof (in themselves),[1] will not decay, and are impervious to insect damage. Painting costs and maintenance are related only to the care in application and choice of paint.

Foundations are only as good as the soil they are set upon. A developer may use a tract which ranges, in physical characteristics, from marshy shoreline to sand ridge or savannah; and with hydraulic fill and bulldozers, convert the tract to one of uniform appearance. With streets and sidewalks added, the lot purchaser has little to clue him about the soil he has chosen to build upon. It is worthwhile for the potential purchaser of a plot or an existing house to follow the advice in the bulletin "Know the Soil You Build On."[2] In this bulletin, it notes that most areas have had soil maps prepared. Often these have used high quality aerial photographs in their preparations. The potential plot purchaser should look at these photographs for himself. From these, he may see what the geographical features were prior to site preparation. If the preparation was done prior to the photographs, he may note what geographical features were interrupted, such as shore lines, swamps, ponds, etc.

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[1]Fires in masonry shell buildings may actually be more intense than buildings with combustible shells, [see Paul L. Kirk, Fire Investigation (New York: John Wiley & Sons, Inc., 1969), p. 207].

[2]U.S. Department of Agriculture, Know the Soil You Build On, Agricultural Information Bulletin 320 (Washington, D.C.: Government Printing Office, 1967), pp. 1-13.

The housing site failures in Florida, due to sinkhole cave-ins, have been well publicized; but much more frequent is the insidiously slow break-up of houses built over soil with high organic content. There is a continuous settling, increasing its rate in the dry periods. A few contractors offer a service for leveling cement block structures which have settled due to poor soil conditions. A slurry of concrete and sand is pumped into the soil beneath the structures, lifting the settled portions to their former positions. Twigs and other vegetation may be ejected from several yards down, while pumping points are being established. The re-leveling can only be temporary when such a depth of organic material is indicated. In certain areas, test borings could determine site suitability.

E. Innovations

Tilt-Up Construction

Tilt-up panels are concrete panels cast on the site, using minimum forming and tilted to upright position. To use this system, the wall construction would commence after the floor slab had been poured integral with the footer. This slab would include column steel protruding at the proper locations. A bond breaker, such as sheet polyethylene plastic, would be laid on the floor slab. A simple edge form of 2 x 4 in. will form the 8-foot square panels with one edge at the proper location for tilting into place. Attachment points for a frame to provide a tilting movement arm are cast into the panel. A truck or tractor provides the power for tilting. The panels are braced in the vertical position. Columns are then formed and poured, linking the panels and holding them upright.[1]

The total cost of tilt-up construction, including columns, is $1.30 to $2.30 per square foot.[2]

A comparision of tilt-up construction with cement block floor level to ceiling is shown below:

	Cement Block	Tilt-up	
Material	$4.27	Min.	Max.
Labor	$7.68	$1.30 sq. ft.	$2.30 sq. ft.
	$11.95	$10.40	$18.40

The price of tilt-up construction is not competitive, but it may offer possibilities for the do-it-yourselfer.

Loading bearing is not permitted on a poured wall of less than six inches in thickness; therefore, the roof load must rest on the columns, which are spaced eight feet apart.[3] Further complications are caused by rough plumbing, which prevents total use of floor space for forming. Corners are still another problem. Only one slab can be cast at a time in these locations.

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[1]Detailed design of tilt-up panels is given in U.S. Department of Agriculture, Use of Concrete on the Farm, Farmer's Bulletin No. 2203 (Washington, D.C.: Government Printing Office, January 1970), pp. 29-30.

[2]Godfrey, Building Construction Cost Data 1970, p. 41.

[3]Southern Building Code Congress, Southern Standard Building Code, Section 1404.2.

The tilt-up panel is limited to use in rooms without rough plumbing and where the roof system requires few support points.

Tilt-up panels can be site-fabricated to include wiring or at least wiring ductwork and insulation. Insulation may be included as a rigid core of foam insulating material for a 5-1/2 inch total thickness of the wall. Building codes require that walls with such cavities must be linked to each other with corrosion-resistant ties at specified intervals. A typical design will use mesh reinforcing running with the concrete panel faces, and small truss-like pieces linking the concrete faces to each other through the insulation.

Examples of tilt-up construction can be found in both commercial and residential buildings dating from 1912. A variety of tilting techniques can be found which are suitable for the residence panel size.

One attempt at overcoming the labor and skill problem of laying concrete blocks is a product, which purports that "anyone can build with concrete block the easy way, without mortar."[1] The blocks are stacked using metal spacers, which must be cut from thin-gauge metal, to provide mortar joint space. The wall thus placed, is then plastered with a "Surface Bonding Cement." The material costs 10 cents per pound. The error in this system's concept is in believing that plastering is less difficult than laying block. Technically, the system fails by creating concentrated stress

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[1]Bonsal's SUREWALL Surface Bonding Cement.

points at the shim points which cannot be relieved by surface covering.

F. Conclusion

The properly constructed concrete block wall is well suited for Florida homes since masonry has the quantities to resist destruction from high winds, decay, and termites. It has two negative qualities and those are site labor cost and insulating quality. Insulation quality is discussed in Chapter 4. Labor cost must be combatted with new techniques in masonry construction. A stack block system was presented and discounted as not feasible. The tilt-up panel offers real possibilities if two problems are solved. One is clearing floor slab space of rough plumbing stub-ups until after wall erection and the other problem is panel design.

A tilt-up panel which qualifies as load bearing without columns and which requires no lintel forming after tilt-up could revolutionize concrete block home construction. Problems of joint grouting and reinforcing linking have to be solved. Numbers of masonry panel systems are in use today for large, multi-unit buildings and represent a source for practical solutions to the joint and reinforcing problems of tilt-up construction in single-family detached dwellings.

CHAPTER 2

FLOOR AND ROUGH PLUMBING

A. Components

Most of the components and installations result from developments and practices of long standing, such as welded-mesh reinforcing, ready-mixed concrete, fill dirt, and asphalt-treated felt. Plumbing is the exception. Certain plastic drain plumbing is now acceptable under FHA and Southern Standard Building Codes. The acceptable plastic materials are PVC (polyvinyl-chloride) and ABS (acrilonitrile-butadiene-styrene), both of which are solvent welded.

B. Assembly

Preparation for the floor slab begins by filling the foundation row of blocks to the level of the header block or four inches below the finished floor level. A crew of three or more with shovels and tamper machine, dress the level after the fill has been delivered and initially dressed by a small tractor (often provided by the fill-dirt contractor). Plumbers place the waterline copper tubing and cap. Plastic pipe is placed in the fill to provide passage for air-conditioning lines. Drain plumbing of PVC is cemented and capped for testing. Plumbing inspection is made visually and with a leak test. When the rough plumbing is approved, fill is leveled over the plumbing and the vapor barrier laid. The reinforcing mesh is laid on chairs over the vapor barrier and the floor slab preparation is inspected.

When the inspection department gives approval to pour, concrete is placed and finished according to the final floor type. Terrazzo requires a broom finish, others a smooth finish. The construction laborers consist of two or more men, until pouring, then cement finishers will be added to the crew. Two or three men assist with the pouring and sometimes use a power finisher.

C. Cost

C.1. Floor

Floor slab-on-grade floor costs approximately 40 cents per square foot for material and 20 cents per square foot for labor for a total of 60 cents per square foot. This is the most elemental floor, consisting of four inches of concrete reinforced by 6x6-inch, 10-gauge reinforcing mesh.

This system can be cost compared to the plywood over wooden joists floor, since both represent a bare floor which requires some form of covering in order to complete the floor. The slab cost and a wooden alternative is cost compared in Appendix B. The wooden floor system costs over 60 cents per square foot for material alone and without the cost of additional footer required or labor. The wooden floor is, therefore, not remotely competitive.

C.2. Plumbing

Water service has no substitute for the Type K soft temper copper required for under slab use. The limited quantity required results in little impact to total costs.

Drain plumbing may be either of three types; plastic, cast iron, or copper. A January 1973 price list in Appendix B gives a comparison by item of costs for each material.

The list of prices for comparison illustrates relative price and availability. Copper was not stocked sufficiently to assemble a drain system by the supplier whose prices were used for this paper. Also indicative of the trend is Sear's, Roebuck and Company, who once stocked copper drain systems but now sells approved plastic drains instead. Innovations in copper drain systems have made copper highly competitive in multi-story dwellings, which are not covered by this paper. Cast iron stock was complete and in general, price competitive on a per item basis. The difference is in installation labor. PVC requires only cement and a saw to make joints at a rate of about one to two minutes per joint. Cast iron requires lead, a lead pot, okum, pouring forms, tamping tools to make joints at a five to ten minute per joint rate.

D. Quality

The basic slab will survive floods (occurring from leaky hot water heaters or other plumbing failures) and will not rot.

D.1. Termite Protection

Two statements from the FHA Minimum Property Standards define the problem.

> 815-3.5 a. Concrete slab-on-ground construction is extremely difficult to protect with physical barriers. Soil treatment or treated wood is recommended.
>
> 815-3.9 b. Concrete foundations cannot be considered as termite protection in: 1) Slab-on-ground construction except where monolithic slab is permitted.

Distance does not block the subterranean termite, nor does pressure-treated wood. The termites will make a path from the soil, through the joint between the slab and exterior wall, up between the dry wall and concrete block, eating through the pressure-treated wood as necessary and finally to the untreated roof timber.

The monolithic slab is created by using header blocks at floor level so the upper walls will rest on the slab. This construction would not be possible with some forms of slab edge insulation. In that case, soil treatment prior to laying the slab is necessary.

Carefully constructed floor slabs will be as long-lived as any other system in the house. Improperly tamped fill dirt (uneven fill surface), lack of reinforcement in the concrete, and/or improper curing will cause eventual failures in the form of cracks. Improper mix, too much water, or old concrete, will cause surface problems. There is a tendency of the ready-mix truck operators and the concrete finishers to add water to the mix at the job site, to make the concrete flow more readily. To drain the surplus water so the concrete can be finished, the workmen punch holes in the vapor barrier. This same sort of workmanship will also be evidenced by allowing the reinforcement to lie on the bottom rather than pulling it into the concrete. Floor slab quality is determined by workmanship.

D.2. Plumbing

Plumbing quality is largely one of design. The means to clean out the drains must be readily accessible, avoiding use of the vent pipe as clean-out access, which can cause roof damage. Water service should be sized properly to avoid excessive pressure drop. For a high-quality water system, the hammer should be snubbed. Below slab, service waterlines should have protection from direct contact with the earth, since some soils will destroy copper pipes.

<u>E. Innovations</u>

C. E. Peck, vice-president of Owens-Corning Fiberglas Corporation, told the 29th annual convention of the National Association of Home Builders, "Important amounts of the nation's dwindling energy resources are literally escaping through the roofs and walls of the average home." He was selling the benefits of home insulations and seems to have left out the floor when quoted by the <u>Miami Herald</u>.

Insulation of slab-on-grade floors is not required where the annual degree days do not exceed 2,800 or the heating degree days in any one month do not exceed 650.[1] No area in

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[1]U.S. Department of Housing and Urban Development, Federal Housing Administration, <u>Minimum Property Standards for One and Two Living Units</u>, F.H.A. No. 300 (Washington, D.C.: Government Printing Office, January 1965 - revised through June 1972), p. 69, 714-3.46.

Florida is required to insulate the slab-on-grade floor. For example, the maximum degree days recorded for Florida in February of 1972 was 415 at Monticello. The fuel scarcity and resultant price increases may cause these values to be changed downward in the near future to conserve national resources.

A study to find the price of fuel and/or electricity vs. degree days that would make slab-edge insulation cost-effective in areas of Florida should be undertaken. The specific soils, locations, and height above grade factors would be examined to develop rule-of-thumb guides for applying slab-edge insulation. Building Construction Handbook gives the following comparison for slab-edge loss in BTU per hour per linear foot of edge exposed to the outside:

> With 2-inch edge insulation, the rate of heat loss is about 50 in the cold northern sections of the United States, 45 in the temperate zones, 40 in the warm south. Corresponding rates for 1-inch insulation are 60, 55, and 50. With no edge insulation, the rates are 75, 65, and 60.[1]

Material costs appear to be about 28 to 35 cents per linear foot of exterior wall as a maximum.

A four-inch bed of gravel to break the capillary path to the slab is sometimes used in other areas. Gravel is heavy and costs about half the price of concrete, so this would involve considerable material and labor expenses.

Another factor in floor slab effects on room temperature is the mass of the slab acting to dampen temperature

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[1]Frederick S. Merritt, Editor, Building Construction Handbook (New York: McGraw-Hill Book Company, 1965), p. 19-3.

variations. Test huts in South Africa, without air conditioning, with a concrete floor, were almost 3 degrees Fahrenheit cooler than a structure with ventilated timber floor during the time of maximum heat gain in a summer and almost 6 degrees Fahrenheit warmer during the night.

Empirical data must be taken to determine the effect concrete slab floors have on heating and cooling.[1]

F. Conclusion

The cost and quality of the floor and plumbing systems will be difficult to improve upon. Floor slab insulation is the only item which may bear investigation. It is certain that heat transfer through the floor slab exists; the question is the amount. That must be determined empirically for slabs used in Florida. With these values, cost effectiveness of slab-edge insulation can be determined. The potential for energy conservation in a time of increasing energy shortage should be sufficient motivation for an implementation of the slab-edge heat transfer study.

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[1]J. F. van Straaten, Thermal Performances of Buildings, (Amsterdam, London, New York: Elsevier Publishing Company, 1967), p. 89.

CHAPTER 3

ROOF

A. Components

The most popular roof system is wooden-framed and sheathed with a built-up or asphalt shingle covering. It is composed of elements which are readily assembled into the variety of roof shapes which individuals may desire.

The frame elements are factory designed and assembled rafter trusses which are widely available in Florida. Sheathing is 4x8-foot plywood sheets. Prefabricated soffet is available with or without vents, and primed for painting.[1] Prepared faccia boards and various roof and accessory elements are also widely available.

B. Assembly

Rafter trusses up to a 30-foot span are manhandled into position on the lintel by a four-man crew. The crew nails the rafter ties, which are poured in place, to the trusses. The trusses are stabilized laterally with temporary bracing. When sufficient trusses are in place, or when all are in place, sheathing is applied. The sheathing gives all the lateral stability required for most roof designs. Where

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[1]Southern Building Code Congress, Southern Standard Building Code, Section 1707.8(a).

between-truss bracing webbing is required, the truss company's design will specify, and the site crew assembles. Trusses of spans greater than 30 feet require a light mobile crane to put in place, in addition to the four-man crew for assembly. Reduction in per-squar-foot assembly time with longer trusses, off-sets some of the crane cost.

The sheathing effort is rushed to a dry-in state with a layer of felt installed.[1] This is to avoid getting the sheathing wet, causing future problems with the roof covering.

Roof coverings of different compositions, require different crews for installation. Asphalt shingles are placed by carpenters or shingles experts. Built-up roofs can use carpenters but they must add construction labor for the bitumin buggy and gravel handling.

Asphalt shingle bundles are placed along the ridge of the roof, and are laid from the bottom up. Built-up roofing requires a second dry layer of felt, followed by a third and fourth, which are mopped down. A flood coat and addition of an aggregate cover dompletes the job. Edge trim and flashing installation detail is covered under article 904 of FHA Minimum Property Standards.

C. Costs

Costs will be computed per square foot of floor covered, plus a cost per linear foot of exterior wall for overhang. This method of costing should allow estimating costs for

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[1]At this point, the builder can collect 30 percent of the building loan, bringing the total collected to 50 percent.

houses, regardless of the relation between total length of exterior wall and square footage of floor encompassed.

Costs are generalized from costs of a 4 in 12-pitch roof to cover a building 60 x 28 feet with an overhang of two feet.

Truss and sheathing costs total approximately 75 cents per square foot of floor covered. The labor cost runs in range of 14 to 24 cents per square foot. Total cost is 89 to 99 cents per square foot of floor covered. The cost calculations are in Appendix C.

Asphalt shingles may be used on roofs with a pitch of 2 in 12 or better. Built-up roofs may not be used where the pitch is greater than 3 in 12. Cost of 240-pound asphalt shingles is 10.5 cents per square foot and labor is approximately 20 to 30 cents per square foot, for a total of 30 to 42 cents per square foot of roof or 32 to 44 cents per square foot of floor.

The total roof system cost per square foot of floor covered is $1.22 to $1.43.

Eave cost is done separately, since house shape will determine the number of linear feet of eave required. Cost for two-foot overhang, including the soffit, faccia, edge material, sheathing, cover, and labor is $1.62 to $1.75 per linear foot. The truss rafter costs are folded into the floor coverage costs.

C.1. Cost Comparison

Built-up roofing using 15-pound felt, Type II asphalt and aggregate costs 19 to 24 cents per square foot of roof, including labor. Bids for such roof covering are 30 cents per square foot, indicating either some error or the margin required for the contractor. The asphalt shingles were higher priced at 30 to 42 cents per square foot of roof. Details are given in Appendix C.

D. Quality

There is a high failure rate of both types of roof coverings presented. A check of built-up roofs in California found more than half of them with leaks.[1] Local experience indicates such leaks are inexpensive to repair if discovered in time; however, usually, the leaks have existed for some time before discovery, resulting in rot in the structure and damage to the interior. The cause of these leaks is poor workmanship, poor design practices, and age.

One particularly poor practice is the dry-in phased with a delay to final roof covering.[2] The first ply or the shingle underlay becomes wet and swells. After the covering is complete, the first ply shrinks, loosening the cover.

Bad workmanship or poor design is evidenced at roof area junctions. The frame is often improperly fastened at the juncture, and the plys are not run in direction of maximum strength across the junction. Long fibers run with the felt roll, and these should be perpendicular to cracks or junctions.

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[1] C. W. Griffin, Manual of Built-up Roof Systems (New York: McGraw-Hill Book Company, 1970), p. 1.

[2] Ibid., p. 88.

Wind destruction of roof coverings also occurs. Asphalt shingles will lift in high winds, particularly when new and flexible. Very high winds can roll built-up roofs off. Most such blow-offs start with the wind penetrating the roof edge detail, lifting and rolling back the membrane.[1] Taping of the seams in the sheathing and moping down all plys will prevent blow-offs. This is not practiced, to avoid costs and the possible tearing of the covering at the sheathing joints.

Aggregate loss allows photo-chemical oxidation, "aging" the cover and eventually causing leaks. Aggregate loss is due to improper bedding of the gravel in the flood coat.

Gravel stop-strips contract and expand, causing breaks in the cover at the joints of the strips. Leaks from these breaks often go unnoticed until after eave rot has occurred.

On the positive side, plywood sheathing has a minimum of joints, and by use of ply clips; the joints, which are unsupported by framing, can be coupled. Roof traffic, wind pressure flexure, and temperature-caused movements act on a surface which is nearly continuous, thus reducing joint-caused failures in the roof covering.

Contrary to common belief, asphaltic roofing materials are very fire resistant. They are difficult to ignite and are self-extinguishing once ignited.[2]

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[1] Ibid., p. 136.

[2] Kirk, Fire Investigation, p. 218.

E. Innovations

E.1. Pre-coated Plywood

Pre-coated plywood sheathing offers a possibility for roof construction. The sheets would be cut and fitted as they usually are with the exception of the fastening. Nails would puncture the coating and should have neoprene washers or other sealing heads, or adhesives could be used in place of nails.[1] Joints would be the most difficult to seal. Sealant strips dipped in acetone have been used with success, to seal the seams on plywood geodesic domes. To be competitive, coating costs should only add approximately 25 cents per square foot to plywood costs.

E.2. Concrete Lift Slab

A unique roof construction system was the key element in the J. C. Long and Associates proposal for Project Breakthrough.[2] The method used a reusable edge form with a jacking system, whereby a concrete roof could be poured on the slab floor, then lifted to a position above the wall height. The walls are then laid and the roof lowered into place. The jack system consists of screws driven by a 2-3/4 horsepower engine. Material cost is 75 to 80 cents per square foot, including built-up roof.

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[1]Southern Building Code Congress, Southern Standard Building Code, Section 1707.4(b).

[2]U.S. Department of Housing and Urban Development, Federal Housing Administration, Housing Systems Proposal for Project Breakthrough (Washington, D.C.: Government Printing Office, 1971), p. 442.

In the abstract, the detail of how plumbing is installed is missing. Since it is normally under the floor and stubbed above the floor, some alteration of rough plumbing installation is required to adapt the J. C. Long system. The system uses bell and spigot tile placed for vent and other roof openings.

E.3. One-Ply Membrane System

Material Engineering reports the use of asbestos felt and DuPont's Hypalen synthetic rubber as a one-ply roof cover for modular housing units. Its qualities were reported as producing "A roofing material that resists ozone, sunlight, freezing, thawing, and is self-extinguishing in the event of fire."[1]

Difficulties reported elsewhere include: cleanliness requirements of the workers to avoid unsightly tracks and marks and problems with handling of the large sheets being glued. Florida's almost constant breezes, bountiful vegetation, and sand would complicate this cleanliness requirement in on-site use.

Costs are not available, but must be 30 cents per square foot or less to be competitive.

E.4. Factory Fabricated Trusses

Prefabricated trusses are an innovation that has proven successful. Two-thirds of the houses being built in the

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[1]John A. Mock, "Materials Key to Better Lower Cost Housing," Materials Engineering, Volume 76, Number I, July, 1972, p. 23.

United States today use prefabricated roof trusses.

A Miami plant produces a million "Gang-Nail" plates per day, to be used in making trusses. "Using presses or rollers and jigs, the plates permit production of trusses in 1-1/2 minutes, using two $3.50 per-hour men; while on-site, it takes two carpenters 15 minutes to build an inferior product," Business Week quotes Louis Lewis, Sales Manager of Hydro-Air Engineering, Inc., of St. Louis.[1] Local plant and site observations indicate the relationship of times to be accurate, if not the magnitude.

The time-sharing computer design of trusses is in widespread use, eliminating or reducing the need for engineers at the plant. The expansion of computerized design to include panels will give the mini-factory for building prefab home elements a tool to make tightly competitive estimates and bids on custom homes. Eventually, this will eliminate most site fabrication of wood products and succeed modular housing as the most likely method of reducing housing costs.

F. Conclusion

The roof system's cost is satisfactory at the present time but rapid inflation of asphalt products, softwood products and labor costs can be predicted for the immediate future (See Appendix E). This trend will make systems, less affected by cost inflation, become more competitive. A case in point is the lift slab roof, since concrete and steel have

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[1] "Helping Builders Automate Design," Business Week, January 13, 1973, p. 30.

had more stable prices than softwood products. The concrete roof may also improve the quality of the asphalt-type roof membranes. Rot will not occur and no joints would exist to cause expansion failures. All plys of felt are mopped onto concrete roofs so membranes blow-off is eliminated.

Asphalt product price increases give additional incentive for investigation of a plastic coating of the roof's sheathing. A successful coating will reduce site labor and total labor; could be colored and textured; and would not hold leaves and other debris. The coating process is a practical extension of plywood production. Coated plywood, not oiled or painted, but reinforced plastic, is now available for reusable concrete form construciton. The manufacturing techniques for this and other factory coated plywood products could be applied to coating of roof sheathing.

CHAPTER 4

PARTITIONS AND DRYWALL

A. Components

This work is done with a tightly interlaced schedule of electrical, plumbing, and air conditioning work and will be considered together.

Major items are prepared wood for furring, cut nails, sheet ceiling material, metal framed windows, pre-hung interior doors, prepared insulation, electrical components, plumbing components, and air conditioning components.

B. Assembly

Furring of the masonry walls is accomplished by using cut nails, fastening 1x2-inch treated strips to the concrete. Spacing and arrangement depend upon the wall covering. Sheet rock can be placed on parallel horizontal strips placed 16 inches apart. Paneling requires the vertical edges to have support, so additional vertical pieces must be placed or all must be vertical. Ceiling strips are 1x3-inch untreated strips nailed to the bottom cord of the roof trusses. Both of the preceding tasks are performed prior to partitioning to allow free movement of the crew. Strips of 1x6-inch wood are required at the junction point of partition with the exterior walls.

Prior to, or during furring, holes are punched into the interior concrete walls for the switches, receptacles and other electrical junction boxes. Furring strips must allow gaps to route wire.

Two-by-four partition frames are constructed flat about one inch shorter than the floor-to-ceiling strip height to allow tilt-up space.

The bathtubs are installed and partition frames placed around each tub.

Windows are installed using the same tools and skills used for furring the exterior walls. A header and two jamb strips are nailed in place and the windows are set in place. Sliding glass doors are installed in the same way.

Air conditioning ducts are installed in the attic space and outlets are set to finished ceiling or wall level.

Note that one exterior door, usually the street or front door, is left out until all material handling is complete. This leaves a larger space for entrance of workers and avoids door damage.

All circuits are wired prior to drywall installation. Wires must be protected where they pass through furring to prevent nails from being driven into the wire. Heavy-gauge steel plate is nailed in place as protection.

Plumbing must be checked when partitions are placed and enough additional work done to make all drain or water lines accessible for completion of work after drywall is installed.

Overhead drywall is placed first and followed by the walls. Insulation is added prior to or in conjunction with, drywall installation. Wall and ceiling finish and painting are completed prior to door and trim installation. This makes the bulk of the interior painting easier. Floors are covered and the kitchen and bathroom equipment is installed. All doors and trim are installed and finished.

C. Cost

Furring and drywall (1/2-inch) for exterior walls costs 31 to 45 cents per square foot for material. Total labor is 21 to 36 cents per square foot. Total drywall cost is then 52 to 81 cents per square foot. Costs are computed in Appendix D.

Partitions cost approximately 8 cents per side per square foot for frame material and 6 cents for 1/2-inch sheetrock. An additional cost at ends and corners represents the extra frame members required.

Site assembled interior doors cost approximately $21 for material and 3 to 3.4 hours labor.

C.1. Cost Comparison

The drywall selection offers a wide variety. The least expensive is 3/8-inch sheetrock at $1.83 per sheet. Low cost paneling at less than $3.00 per sheet is perhaps the least expensive when the preparation and painting cost for the sheetrock are considered. Other paneling may cost a dollar per square foot or more.

Partition studs can be of metal, which is now cost competitive. Metal studs, 3x3-5/8-inch, cost $105.00 per one thousand linear feet, or $0.105 per foot. Wooden studs are approximately $0.15 per foot.

A comparison of door costs is shown below:

Pre-hung door 3/0	$21.56
Lock set	3.60
Total	$25.16
Site assembled material cost	20.53
Difference	$ 4.63

Pre-hung doors give better quality at a cost savings. The cost difference between the cost of an hour's labor to set the pre-hung door indicates a considerable savings over the 3.0 to 3.4 hours required to total site assembly.

D. Quality

Sheetrock offers fair sound-isolation and good fire resistance, together with a low price. Paul L. Kirk notes:

> The introduction of gypsum board, or sheetrock, is possibly the most important development in developing fire resistance in low- and medium-cost housing that has so far occurred. Not only is it non-combustible; but it will resist fire for considerable periods, thus allowing containment of local fires. Every fire investigator will be struck by the fact that in a building in which extensive burning has occurred, those rooms that are lined with gypsum board invariably show the least destruction.[1]

Its disadvantage is susceptibility to damage by impact and water.

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[1]Kirk, Fire Investigation, p. 209.

Prepared wood paneling gives a finish resistant to damage. It is not as heavy and, therefore, is not as sound-isolating as is sheetrock. Nor is it a fire barrier. A third drawback is that it fixes the decor, refinishing is not practical.

D.1. Quality: Heating and Cooling[1]

Heat loss rates, which govern the application of insulation, are given in the FHA Minimum Property Standards, Section 714-3. Total heat loss is limited to 50 BTUH per square foot of the total floor space when heated to 70 degrees Fahrenheit. Portions of this are assigned as limits for loss through exterior walls, ceiling, and floors. Heat gain limits, when cooling, are given under Section 714-5. The heat gain limits are a sliding scale with the number of square feet of living area and geographical areas design dry bulb temperature determining the maximum calculated heat gain allowable. Maximum gain allowed is 28 BTUH per square foot of floor area.

in August of 1972, the temperatures throughout Florida ranged 20 degrees Fahrenheit from daily average high to aver-low temperatures. The greatest daily average high for the month was registered as 94.2 degrees Fahrenheit at both Milton and Avon Park with all locations recording average

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[1]Climatological Data is extracted from the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Data Service Reports for Florida, Volume 76, No. 2 (February 1972) and No. 8 (August 1972).

maximums of greater than 90 degrees Fahrenheit. Heating demands are much more varied in Florida than cooling demands. Freezing temperatures are experienced in the panhandle, while southernmost Florida is nearly tropical. Insulation would be determined by the extremes of either heating or cooling degree days required for the area.

The unfurred, plain, 8-inch concrete block wall has a .90 BTU conduction per square foot of section, per hour, per degree Fahrenheit temperature difference between the inside and outside air. The poured upper 16 inches has a transmission coefficient of (calculated) 1.04. The furred wall with 3/8-inch gypsum wallboard decreases transmission to a calculated value of .47. In round figures, given a rectangular house with 1,000 square feet of floor and cooling to 70 degrees Fahrenheit on a 90-degree day, the wall heat gain would be 10,560 BTU per hour, not including windows and doors which have a higher gain. This would be half the allowable figure of about 20 BTU per square foot per hour given by FHA. The transmission coefficient can be halved, by using masonry fill such as Zonolite, or greatly reduced with aluminum foil reflective material under the drywall. Insulating the walls after construction is too costly, so careful consideration should be given to the savings and comfort insulation might provide. The application of insulation should be decided prior to construction start.

Ceiling insulation must resist a higher temperature difference than the wall system as the attic space is hotter during the day than the outside air. If a mistake is made in insulating the ceiling, it can generally be corrected, but still at a premium cost.

D.2. Quality: Sound Control[1]

Sound isolation characteristics of the exterior walls gives a loss of about 40 db at 1000 eps. Room-to-room sound isolation at partition walls is much poorer at lower frequencies, but is nearly as good at higher frequencies. Hollow core doors give only 13 db transmission loss at 1000 eps. Solid core doors raise the loss to 18 db.

Sound absorption is largely dependent upon surface condition and finish. For example, 1/2-inch Gypsum board nailed to 2x4's 16-inch O.C. reflect 96% of the impenging 1000 cps sound. If the walls were draped for half the area in 18-ounce per square yard velour, the sound reflection would be 28% at 1000 cps. Bare concrete floor is particularly bad, reflecting at least 98% of the sound at any frequency. Heavy carpet on backing reflects only 31% of 1000 cps sound.

Water pipe noise can be reduced by isolating pipes from direct contact with partitions. This is not commonly done, but it can be easily accomplished, thereby reducing the plumbing noise.

The nature of the furnishings will exercise considerable control over sound reflection.

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[1]Acoustic Data is from Time-Saver Standards, A Handbook of Architectural Design, Table 2 on page 619 and Table 4 on page 627.

Insulation in partition walls does not give effective control of transmitted sound. Insulation does not have the necessary mass to isolate sound.

E. Innovations

These systems, partitions, and drywall, have a high labor cost. Any change of system which can reduce labor should be re-examined.

Using plasterer's stilts and a nail gun can greatly speed the ceiling strip installation. Nail guns suitable for the masonry wall furring would reduce labor on this job.

Punching holes in the masonry for electrical juncture boxes could be eliminated by redesign of this system. The box size is determined largely by the need for space to fold the wire into, after the end item (switch, receptacle, or light fixture) has been wired. If the box had terminal posts for the wire, the connection could be made flat in the box without pigtails. The end item could plug-in with 1/2-inch depth tolerance to allow for drywall thickness variations.

Prebuilt partition walls are possible but require a different construction flow, since the roof area would be required for passage of the walls.

F. Conclusion

Qualities of sound control and thermal insulation are less than adequate for today's needs.

Television, stereophonic magnetic tape and disc record players, radios, dishwashing machines, blenders, garbage disposals, trash compactors, air-conditioners, motorcycles, and increased population density are creating mind-bending levels of sound. The concrete block exterior wall gives good sound isolation, but it is bypassed by windows and a roof and ceiling path. Gypsum board partition walls give fair isolation, but they are inadequate for the sound levels generated by home appliances. Homes may have to create sound zones, using masonry partition walls and heavy, gasketed, interior doors.

With the increasing cost of electrical power, today's thermal insulation practices are inadequate for air-conditioned homes. Homes must be insulated to the degree cost effective and not just to the minimum standards of the builders' lending agency.

Fire control is improved by Gypsum wallboard, but fire prevention measures are the best control, since no furnished residence is fireproof.

Labor-saving devices for on-site use are a stop-gap measure until some method is developed to use the kitchen and bathroom module and factory-assembled partition walls. These prefabricated systems require weather protection; and as concrete block homes are now assembled, the dry-in state creates a box with nothing larger than a door or perhaps a double door for material entry.

The masonry wall may literally block innovations of the immediate future unless this access problem is solved.

CHAPTER 5

KITCHEN, BATHROOM, AND UTILITY ROOM

A. Components

Kitchens have fully assembled cabinets, countertops, range tops, oven units, garbage compactors, garbage disposals, and sinks available.

Bathrooms have matched or mixed sets of lavatory sink, toilet, and bathtub. Medicine cabinets, vent fans, shower stalls, and tub inclosures are other major bathroom components. Both kitchens and bathrooms may use special wall and floor covering to provide soil-resistant, attractive, and easily cleaned surfaces.

A utility area has a washing machine, clothes dryer, and a water heater.

B. Assembly

The most difficult work is done when the plumbing is correctly roughed in. Floor and wall covering should be done first. Wall cabinets can then be hung, while the floor space is clear. The base cabinets are placed and the countertop has the sink and range openings cut. The countertop is fastened to the base cabinets, while plumbing and wiring is completed as required. The oven is installed in its cabinet and is connected to either gas or electricity. The bathroom assembly is begun with the tub already installed. The valves for the tub are concealed in the wall and the drain and overflow are concealed, which requires installation prior to the partition wall assembly. The wall and floor covering is installed and medicine cabinet and vent fan placed. Vanity and toilet are then placed and plumbed.

C. Costs

Cost is associated with the various forms of quality. A 96-inch sink, base cabinets and countertop cost $270 for a simulated walnut finish or $330 for a pecan finish.

Toilets can range from a noisy, standard two-piece (tank and bowl) item for $30 to a stylized one-piece ultra-quiet gem of a toilet for $120. Faucet sets also have a large range of quality and prices. There are the washer-type to the washerless-type; there are chrome-plated to gold-plated, and so it goes for every item.

Labor costs are low compared to total costs as a result of minimal site labor. Ordinary carpenter labor can install all of the cabinets and prepare the countertop for sink and range. Plumbing labor requires some cut and fit, but nothing of major importance.

D. Quality

D.1. Kitchen

Minimum areas of countertops, shelves, and drawers are specified in FHA Minimum Standards, Section 602-5. The minimum wall and base shelving is 20 square feet each with the total having a minimum of fifty square feet. Countertop space must have eleven or more square feet, exclusive of sink and range areas.

Drawer space minimum is eleven square feet. This type regulation seems overly restrictive, considering the prepared foods used today, which take less space to make ready for serving. Very few kitchens are fully utilized--but few home buyers will, even when given the opportunity, reduce or streamline the traditional kitchen setting.

D.2. Hazards

Minor cooking fires only damage the utensils involved. The range hood, with fan running, will eliminate most of the heat and smoke. The larger fires, as from deep fryers, or when forced venting is inoperative, cause extensive smoke damage.

The incidence of such fires has caused some high-rise apartments to use fire monitors in each kitchen. Nothing has been done to make fireproof the residential cooking area. The cost would be prohibitive to install hoods and vents of sufficient size. Temperature regulating ovens, individual electrical items, and range burners are of some aid, but all of them have a temperature range which includes ignition temperatures of the foodstuffs when cooked dry.

Water is the second household hazard readily available in the kitchen. The usual kitchen sink design does not have an overflow and the result is occasional flooding.

D.3. Bathrooms

Quality of bathrooms depends upon price and layout. Buy a sufficient quality toilet and it will not overflow. High-quality washerless faucets will require less maintenance. Quality bathrooms are not cheap but can be purchased.

E. Innovations

Westinghouse Electric proposed for Project Breakthrough, a "Study of plumbing systems to develop cost reductions; development of plumbing walls, appliance centers, utility cores, unitized kitchens and bathrooms."[1] Their abstract further states: "Recognizing that no major cost reductions are to be expected in the individual components which make up the basic service subsystems in a dwelling--that is, heating, ventilation and air conditioning, electrical distribution, plumbing, and appliances--the proposer instead intends to concentrate on achieving overall savings and higher production rates by better integration of these subsystems with the building structure."

Factory assembled utility cores are used in factory fabricated homes. The core contains the sink and countertop area of the kitchen and one or two complete bathrooms. The advantage to the builder is to take the "tedious, expensive, uncontrollable, mechanical work out of the field and allow them to have it done by semi-skilled people under

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[1]Department of Housing and Urban Development, Project Breakthrough, p. 564.

controlled conditions."[1] Some major changes in sequence and method of construction would have to be devised to accommodate the prefabricated mechanical core in current concrete block home construction. Single modular bathrooms are available, but they have not been adapted to slab-on-ground concrete block houses. Sub units, such as modular tub and shower units of reinforced plastic, are now mass produced. A four element version by Owens-Corning Fiberglas could be used in the site assembled concrete block house without alternation of work force or flow.

Expending some effort to improve conventional plumbing system installation might be worthwhile as an interim measure for reducing site labor.

The stop cock, supply pipes, and fittings which constitute the assembly from the stubbed-up water supply system to fixture, might be standardized as single units, comprising all necessary parts needing only to be connected to the supply and the fixture. These units would be used for the kitchen sink, and bathroom lavatory and commode.

The bath tub and/or shower remains the most difficult and costly item for which to install water service. The volume of water used by the bath tub, at one time, requires larger service to draw sufficient water in a reasonable time span. This is complicated by the tradition of concealing

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[1]Marvin C. Schuette, "Utility Core and Panels," Systems Building News, November, 1972, p. 21.

the fixture's valve body within the wall or tub. Installation and maintenance would be easier if the service water pipes came through the wall for connection to the valve and the pipe and the valve body were then covered, after connection by a decorative and protective cover styled to match the bath tub. The tub drain is also difficult to connect and complicated by the floor slab-on-ground.

In time, competitive items will penetrate the market.

F. Conclusion

The components of the kitchen and bathroom have a cost and quality imparted by their designers and manufacturers. They then impact home cost exogenously and are beyond the scope of this paper.

SUMMARY

The shell cost is about one-third of the total cost of home and land. Of this cost, about one-half is labor expended on-site. Material and labor costs are, therefore, equally important.

The Labor Department reports wage increases for union building industry craftsmen is 12.7 percent from October of 1971 and 8.2 percent for the following year's period ending October 1972. Average hourly wage was $8.55 an hour, including fringe benefits.

Much of the effort to control labor cost is directed toward removing labor from the site by performing the tasks in a plant or factory, where factory conditions reduce the labor required per task and the wage rate is generally lower than on site. Mechanization is the other method for reducing labor.

Exterior walls had a particularly large labor factor. The alternative is concrete panels which are currently in wide use on large buildings. A fallacy of this type structure has been extensive site labor to fit and grout the panels into place. Site assembly of concrete block walls does not currently have a viable alternative but its price will continue to make it a target for innovation.

Extensive use of inexpensive gasoline-powered tamping machines, small cable trench diggers, and powered cement finishers are reducing labor costs. Machine costs are so low that there will probably be more effort toward mechanizing various site tasks.

Material delivery has its labor cost which is generally folded into material price. Concrete block suppliers have been particularly innovative and progressive. Two decades ago, small orders of concrete block were delivered with a crew to unload by hand; today, trucks equipped with knuckle booms and special palletless lift devices deliver concrete block, using only a driver. Concrete has been delivered ready-mixed throughout the past years, but the size of the trucks has grown and their ability off-road has greatly improved. All-wheel drive and special tires have been a boon to sandy Florida's construction sites.

The roof system assembly has had much of its site labor transferred to factory. Plywood sheathing and factory built rafter trusses save a great amount of site labor while giving excellent quality.

The earth moving labor has improved. Small tractors with hydraulicly operated equipment makes possible speedy and inexpensive dress of yard and floor fill. Light, mobile cranes and back-hoes allow extensive building lot grading at reasonable prices.[1] The latter is particularly important in many areas of Florida where excellently located lots with

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[1]The writer had a small island and pond created and about 6000 square feet of land filled for a cost of $230 in early 1972.

poor elevation needed improvement before use as home sites.

Material costs are rising. About eighteen years ago, stretcher block cost 20 to 25 cents each; today, they cost 32 cents. Compare that to pressure treated pine which rose in that same period from $120 per thousand board feet to $240 per thousand. To compound the wood price rise, there was a reduction in standard size in the same period.[1] Percentage change index for the period 1966-71, in average annual rate, and the 1970-71 changes are listed for comparison of the materials involved in the shell.[2]

	1966-71	1970-71
Ready-mixed concrete	+4.6	+8.0
Southern pine	+6.0	+16.0
Concrete block	+3.7	+4.5
Reinforcing bars	+3.0	+7.2
Plywood	+2.0	+5.7
Prepared asphalt roofing	+4.3	+24.0
Gypsum wallboard	-0.3	+6.7

Appendix E has calculations which illustrate the impact of material cost increases on the home's shell cost.

It appears that dimensional lumber has begun to be replaced by steel and aluminum elements. Steel and aluminum studs for partitions and exterior framing is now widely used.

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[1]U.S. Department of Commerce, "American Lumber Standards for Softwood Lumber," Federal Register, XXXIV, No. 233, December 5, 1969, 19323.

[2]Table #1 of Construction Review, U.S. Department of Commerce, "Construction Materials Prices During Phase I and Phase II," August, 1972.

Current lumber prices and the probable increases will accelerate the switch to metal studs. The steel studs will be supplied by the dealer who supplies your rebars as a companion product. Even the truss manufacturers may switch to metal members and an entirely new factory system. Alcoa has already made an aluminum truss for home use.

As material costs continue to climb, concrete producers have done their part by combating production costs with improved production equipment and delivery equipment.[1] This has reflected in the relative stability of their prices.

Not to be overlooked is the tiny ply clip which is a labor and material saver. Without the ply clip to fasten the plywood edges to each other, 1/2-inch plywood could not span rafters two feet on center, purlins of some kind would be needed at additional material and labor cost.

Housing will become much more expensive if the trend continues. Perhaps some good will come of the cost pressures, for they are providing the overriding rationale for innovation in the building industry.

Without proper quality, costs are meaningless. Roof covering or membrane was the major flaw in the roof system's overall quality picture. It is very much a manual labor task and does not equal the durability or quality of the

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[1]An example of the automation in Florida's concrete block plants is Concrete Products Company's new Tampa plant reported on p. 38 in the December 1972 issue of Concrete Products.

other systems in the shell. Various membranes are being used and may find their way into Florida's home construction.[1]

The insulating quality of the walls is inherently good enough for most of Florida, or was, until air conditioning became the norm. It is now clear, with brown-outs, fuel shortages, and higher prices for power, that the economics of the home's insulation must be reconsidered. A wall that can gain over 10,000 BTU an hour on a normal summer day may well be so expensive that there is profit in filling the walls with vermiculite to halve the gain. State and Federal regulatory agencies may not wait for the financial pressures to drive builders to better insulation. Factory-fixed adjustment limits of thermostats are already proposed for Florida. Heating degree days were originally predicted on the empirical data that home occupants will turn heating systems on at 65 degrees Fahrenheit of outside temperature. A state regulated "on" temperature for heating and cooling is certainly an Orwellian approach to the problem.

Insulation needs, of course, include the ceiling which is readily done and is a matter of spending sufficient money to get a degree of insulation which is greater than the current minimums. A study of floor slab edge insulation has already been suggested--windows are a high loss (or gain) item not covered in this paper but they must be considered in the wall calculations.

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[1]"New Roofing Membranes," Chapter 12 of the Manual of Built-up Roof Systems.

The concrete block home is viable for the near future and well suited for Florida's location, which is rated by the FHA as a region of maximum suceptibility to high winds, termite infestation, decay hazard, and intense rainfall. Care and skill during construction will protect the investment from the hazards and require a minimum of maintenance.

APPENDIX A

EXTERIOR WALL COSTS

A. Material Costs

1. Wall material costs (floor-level to ceiling, 8-feet high x 1-foot long):

Lintel Block, 4/3 sq. ft. @ $.405	=	$ .54
Regular Block, 20/3 sq. ft. @ $.3487	=	$2.325
No. 5 Reinforcing Rod, 2 linear ft. @ $.105	=	$ .21
Lintel Concrete, 1/50 yd. @ $21.90	=	$ .438
Tar Paper Concrete Stop--negligible costs		
Mortar, 8 sq. ft. @ $.0949 per sq. ft.	=	$ .7592
Total		$4.2722

2. Footer costs to floor level:

Minimum 16x8-inch footer concrete, 8/9 cu. ft. @ $.81/cu. ft.	=	$ .72
Two Courses Regular Block, 4/3 sq. ft. @ $.3487/sq. ft.	=	$ .413
No. 5 Reinforcing Rod, 2 linear ft. @ $.105	=	$ .21
Mortar	=	$ .11
Total		$1.453

3. Pilasters:

8 ft. x 6 in. x 6 in. Section of Concrete, (2 cu. ft. @ \$.81/cu. ft.)	=	\$1.62
13 ft. No. 5 Reinforcing Rod @ \$.105/ft.	=	\$1.36
Total		\$2.98

4. Window:

Pre-cast Lintels Range 34 in. to 90 in., \$3.30 to \$9.45, approximate cost per ft.	=	\$1.20
Through Wall Sills Range 19 in. to 74 in., \$1.70 to \$6.70, approximate cost per ft.	=	\$1.08
Total		\$2.28

Add per window 1 ft. lintel overspan　　\$ .84

Deduct per ft. one row lintel block 2/3 sq. ft. @ \$.54/ sq. ft.　　\$ .36

Regular Block Window Height Ft. x \$.35　　h(\$ .35)

Add per Window

Half Block Usage

Half Block (\$.59) sq. ft. - Regular Block (\$.35) sq. ft. (\$.59 - \$.35)(2/3) (Window ht)　　h(\$ .14)

Per Linear (Window Width) Foot Cost \$2.28 - \$.36　　= \$1.92

Per Window Height Cost (\$.14-\$.35)h　　= (\$-.21)h

Fixed Addition per Window　　= \$ .84

Example: 37 x 38-5/8-inch Single Hung Window　　= \$13.43

Width Cost (3)(1.92)　　\$5.76

Example (Continued):

Height Cost (3) (-.21)	$-.63		
Fixed Addition	$ .84		
Wall Opening Cost		=	$5.97
	Total		$19.40

5. Door:

Add Door Header (Pre-cast) 3/0 Door		=	$5.95
Deduct Row of Lintel Block		=	$1.08
Deduct Regular Block, 20 sq. ft. @ $.35/sq. ft.		=	$7.00
Add Half Block Usage 6-2/3 ft. ($.14)		=	$ .93
	Total		-$1.20

B. Labor Costs

Block laying 9-1/3 sq. ft. @ $.90 per sq. ft.		=	$8.40
Footing form 4/9 S.F.C.A. @ $.69 per S.F.C.A.		=	$ .31
Footing excavation 8/9 sq. ft. @ est. $.30		=	$ .27
Pour lintel 1/50 cu. yd. @ $24/yd.		=	$ .48
	Total		$9.46

APPENDIX B

PLUMBING AND FLOOR SLAB COSTS

A. Plumbing Costs

1. Drain Costs:

Part	PVC	Cast Iron		Copper
1-1/2-inch pipe	$.247	galv.	$.50	$1.04
3-inch pipe	$.59		$.80	$4.33
3-inch coupling	$.65	----------		$3.72
3-inchx1-1/2-inch sanitary tee	$1.50	3"x2"	$3.24	
90-degree elbow 1-1/2-inch	$.26	2"	$ .90	$ .90
90-degree elbow 3-inch	$1.20		$1.38	$6.35
3-inchx4-inch reducing closet flange	$2.35		$1.10	-----
45-degree elbow 3-inch	$1.05		$1.18	-----
"p" trap with union 1-1/2-inch	$.95			
1-1/2-inch to 1-1/4-inch trap adpt.	$.45			
1-1/2-inch to 1-1/2-inch trap adaptor	$.45		$1.70	
Threaded Cleanout	$.60		$1.29	
Y-Branch 3-inch	$2.20		$2.84	

2. Water Service Costs:

Type K Soft Temper

1/2-inch, $0.59 per ft.

3/4-inch, $43.89 per sixty-ft. roll

B. Floor Slab Costs

1. Material Costs:

Fill approximately 12-inches deep @ $2.70 per cu. yd. delivered and spread	=	$ .10 cu.ft.
Vapor barrier (6 mil)	=	$ .011 sq.ft.
6x6-inch 10-gauge reinforcing	=	$ .027 sq.ft.
Concrete 4-inch thick	=	$ .27 sq.ft.
Total		$ .408 sq.ft.

2. Labor Costs:

3-man crew one day per house

Fill dress and tamping	=	$ .10 sq.ft.
Vapor barrier, reinforcing pour and finish	=	$ .10 sq.ft.
Total		$ .20 sq.ft.

3. Cost Comparison to Wooden Floor System:

Substitute plywood so that various floor covering can be used directly (FHA 817-3.2).

1/2-inch Southern Pine flooring	$.305	sq. ft.
2x8 #2 Pine 16-inch centers, 12-foot span joints	$.27	supporting a sq. ft.
2x4-inch plates for joist ref. FHA 816-5.1	$.03	supporting a sq. ft.
Total	$.605	

APPENDIX C

ROOF COSTS

Truss costs total approximately $900.00 for a 30x60-foot building.

Truss costs per sq. ft. of floor	=	$ .52
Sheathing, 1/2-inch Southern Pine plywood, per sq. ft. of roof	=	$ .187
Total		$ .707
Multiply by pitch factor, 1.054	=	$ .745 sq.ft. floor

Labor cost to dry-in is estimated:

48 manhours @ $5 to $8 per hour	=	$240 to $400 total
Labor cost per square foot covered	=	$.14 to $.235

240-pound asphalt shingles cost $10.49 per square

Material cost per sq. ft. of roof	=	$ .105

Labor cost, 4 carpenter hours per square on simple roof @ $5 to $8 per hour

Labor cost per sq. ft. of roof	=	$ .20 to $ .32

Total roof costs per square foot of floor:

Trusses	=	$ .52
Sheathing	=	$ .187
Frame Labor	=	$ .14 to $ .235
Cover Material	=	$ .105
Cover Labor	=	$ .20 to $ .32
Total Cost per sq. ft. of roof	=	$1.153 to $1.367
Adjusted for floor coverage	=	$1.22 to $1.44

Eave Costs:

For two-foot eave

Soffit 24-inch x 12-ft. vented, $5.95

Cost per linear foot	=	$ .50

Faccia 6-inch x 16-ft., $3.05

Cost per linear foot	=	$ .19
Edge Material per foot	=	$ .135

Cover and sheathing, including labor

Per square foot, $.40 to $.46

Per linear foot	=	$ .80 to $ .92
Total cost per linear foot	=	$1.62 to $1.75

Built-up Roofing Costs using 15-pound Felt

Felt, $3.60 for roll to cover one square with 4-ply

Felt cost per square foot	=	$.036

Type II Asphalt 100-pound per square at $.30 per 100-pound

Asphalt cost per square foot	=	$.033

Aggregate, 4 pounds per sq. ft.

1500 lbs. per yard at $10.50

Aggregate cost per square foot	=	$.028
Fuel and Mops, per square foot	=	$.001
Labor, 1.8 hours per square at $5 to $8 per hour, per sq. ft.	=	$.09 to $.14
Total	=	$.188 to $.238
Compare to asphalt shingles costs		$.30 to $.42

APPENDIX D

DRYWALL, PARTITION, AND INTERIOR DOOR COSTS

A. Placing Drywall to Exterior Walls

1. Materials:

Furring, 1x2-inch treated @ \$.041 per linear foot		
Per linear foot of wall	=	\$.287
Per square foot of wall	=	\$.035
3/8-inch sheetrock @ \$1.83 per panel		
Square foot	=	\$.06
1/2-inch sheetrock @ \$2.94 per panel		
Square foot	=	\$.092

2. Labor:

Furring, 1.5 hours per 100 linear ft.		
Per linear foot	=	\$.075 to \$.12
Per square foot of wall	=	\$.065 to \$.105
Drywall, .67 to 1.0 minutes per square foot		
Labor cost per square foot	=	\$.055 to \$.13
Total		\$.215 to \$.362

B. Partition

1. Materials:

One header and one base, plus studs

16-inch on center, one linear foot per square foot of wall

8-foot long, 2x4-inch stud quality @ $1.19 each, cost per sq. foot of partition	=	$.15
Both sides are used, per side		$.075

Add $2.38 per corner

$1.20 per end

2. Labor:

Framing and erecting interior stud partition, 20 carpenters and 6 laborers per 1000 board foot, $5 to $8 carpenter, $2.50 to $3.50 laborers

$100 carpenters, $15 laborers to $160 carpenters, $21 laborers

Per board foot	$.115 to $.181
Per square foot	$.076 to $.1206
Per square foot per side	$.038 to $.0603
Add per corner and twice that per end	$.608 to $.96
Total	$.113 to $.1353

C. Interior Door Costs

1. Materials:

Door 3/0 flush interior	$7.00
Jamb set 3/4-inch x 5/8-inch	$5.20
Casing $.14/ft.	$4.20
Hinges and lock set	$4.13
Total	$20.53

2. Labor:

Ordinary carpentry man hours

Setting jambs	.8 - 1.0 hrs.
Casing both sides	1.0 - 1.2 hrs.
Fitting and hanging doors	0.8 hrs.
Using power router and mortiser	0.4 hrs.
Total	3.0 - 3.4 hrs.

APPENDIX E

SAMPLE SHELL COSTS

30 x 60-foot Concrete Block Shell with Ten Openings and Two Door Openings

Material	Unit Cost	Total Cost	Product Sum	Percent of Total	Inflation Impact on Percent of Total
Concrete Block Products					
Linear foot of wall	4.148	746.64	803.94	24	1.0
Ready-Mix Concrete					
Per ft. lintel & footer	1.158	208.44	700.92	21	1.0
Pilasters	1.62	6.48			
Per sq. ft. floor	.27	486.00			
Steel					
Linear ft. reinforcing rod	.42	75.60	146.88	4.4	1.3
Sq. ft. reinforcing mesh	.027	48.60			
Linear ft. roof edge material	.135	22.68			
Wood Products					
Roof trusses		9.00	1424.82	43	2.6
Sq. ft. sheathing	.187	354.78[1]			
Linear ft. eaves	.374	70.32			
Linear ft. soffet	.50	64.00			
Linear ft. faccia	.19	35.72			
Asphalt Products					
Sq. ft. shingles	.105	199.21[1]	238.69	7	.3
Sq. ft. felt	.008				
Linear ft. eave	.21				
Yearly impact at 1966-71 rate					6.2

[1]1.054 slope factor added

The impact of the 1970-71 rate of material cost increases is computed to be 12.6 percent of total cost.

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